

Surface Residue, Water Application, and Soil Texture Effects on Water Accumulation¹

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ABSTRACT

Surface residue rates and water application amounts affect evaporation from soil. These factors were evaluated for their effects on water accumulation in a clay loam and a fine sandy loam soil. Surface residue rates ranged from 0 to 12,000 kg/ha and water was added at 0.25, 0.5, 1.0, or 2.0 cm/addition. At low residue rates and water applications, little or no water accumulated in the soils. The amount of water that accumulated in the soils increased as surface residue rates and water applications increased. Results for the two soils were remarkably similar, apparently because the liquid and vapor flow characteristics for the two soils were similar at high water contents, even though their water retention characteristics differed markedly. The results of this laboratory study are discussed with regard to residue management practices for low (dryland) and high (irrigated) residue production systems of the Great Plains.

Additional Index words: soil water evaporation, soil water storage, residue management, Pullman clay loam, Amarillo fine sandy loam.

P RECIPITATION in the southern Great Plains is erratic in amount and distribution, and annual potential evaporation greatly exceeds annual precipitation. For these reasons and others resulting from weed control and tillage practices and soil conditions, soil water storage from precipitation generally is low. Long-term precipitation storage efficiencies during fallow ranged from 15 to 25% for the Great Plains (Mathews and Army, 1960) with the lower value also common for the southern Great Plains under common cropping practices of wheat (*Triticum aestivum* L.)-fallow and wheat-sorghum (*Sorghum bicolor* [L.] Moench)-fallow (Unger, 1972).

Recently, precipitation storage efficiencies were increased when crop residues at high levels were maintained on the soil surface during fallow (Unger et al., 1971; Unger and Parker, 1975). In addition, Bond and Willis (1969, 1970, and 1971) showed that surface residues reduced evaporation from soil columns under controlled conditions, and Gardner and Gardner (1969) showed that amount and frequency of water application influenced evaporation and storage of soil water. In this study, the influence of surface residue rates and water application amounts on water accumulation in two soils of widely different textures and, hence, water-holding capacities, was determined.

EXPERIMENTAL PROCEDURE

Pullman clay loam (cl) and Amarillo fine sand loam (fsl) were air dried, passed through a 2-mm sieve, and packed with a vibrating packer into 10.2-cm diameter polyvinyl chloride (PVC) columns that were 61 cm tall. The final soil height in the columns was 56 cm, allowing 5 cm for placing residues and adding water. Average packed densities were 1.30 and 1.50 g/cm³ for Pullman cl and Amarillo fsl, respectively. Wheat residues cut in about 5-cm lengths were placed on the soil surfaces at 0 (check), 1,000,

2,000, 4,000, 8,000, or 12,000 kg/ha. Each treatment was replicated twice.

The columns were placed at the outer edge of a 114-cm diameter turntable that rotated at 1.2 rpm. Six 125-W heat lamps placed 46 cm above the columns provided energy for evaporation. The lamps were on 16 hours during each 24-hour period. Water was added at the light-period midpoints when lamps were turned off briefly. An electric fan circulated air around the columns but did not blow across the column tops. The experiment was conducted in a room where the ambient temperature was 25±1°C and the relative humidity varied between 46 and 60%.

For a 14-day period, 0.25 cm of water was added to the surface of each column on each Friday, Monday, and Wednesday. The first Friday was Day 0. During three subsequent 14-day periods, 0.5, 1.0, or 2.0 cm of water were added to the water already in the soil on the same days unless a soil column was near the water content associated with the -1/3 bar matric potential. If a column was at this water content, no additional water was added to that column. Water contents at -1/3 bar potential for Pullman cl and Amarillo fsl were 33.8 and 14.9% by volume, respectively, which were equivalent to 18.9 and 8.3 cm of water. Water contents were determined by weighing the columns before adding water on a particular day. Potential evaporation was determined from water losses from a water column filled to the 56-cm height and placed on the turntable. The water column was refilled each time the soil columns were weighed.

The water accumulation data were analyzed by the analysis of variance technique. Least significant differences were calculated to show which treatment means were significantly different from the check treatment (0 kg/ha residues) mean.

RESULTS AND DISCUSSION

Figures 1 and 2 show the influences of residue rates and total water added during successive 14-day periods on the percentage of the added water accumulated in Pullman clay loam (cl) and Amarillo fine sandy loam (fsl), respectively. Least significant differences are given in the figure legends. Figures 1 and 2 also show the percentages of the total added water that were stored in the soils during periods when water additions for all treatments were identical (56 days for Pullman cl and 42 days for Amarillo fsl).

The results shown in Fig. 1 and 2 are based on water additions and gains occurring during successive 14-day periods. During the second, third, and fourth periods, the water was added to that already in the soil, which undoubtedly influenced water storage during these periods to some degree. However, the degree of influence is unknown and not obtainable from this experiment. Consequently, it is disregarded in subsequent discussions.

Water additions totaled 22.5 cm unless soil columns approached the -1/3 bar potential before adding that much water. At 56 days, no Pullman cl columns had approached the -1/3 bar potential. All Amarillo fsl columns, except the check (0 kg/ha residues), had approached the -1/3 bar potential at 42 days. Hence, only the Amarillo fsl check column received water during the last 14-day period.

Increasing residue rates and water applications during a 14-day period increased the percentage of water stored in soil, except during the initial 14-day period when only the higher residue rates resulted in greater water storage. Although Pullman cl and Amarillo fsl differed greatly in water

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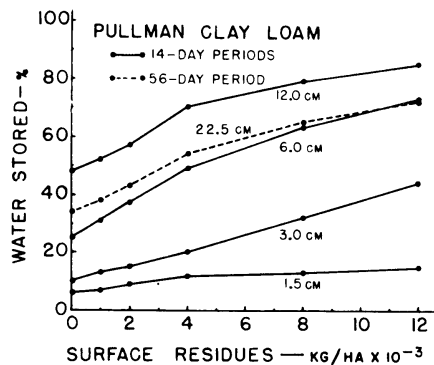


Fig. 1—Water stored in Pullman clay loam during successive 14-day periods and the entire 56-day period. Total water added is shown by numbers at the lines. Least significant differences (0.05 level) were 3.2, 2.2, 2.5, and 1.2% when 1.5, 3.0, 6.0, or 12.0 cm of water were added, respectively.

retention at $-1/3$ bar potential, water accumulations in the two soils were remarkably similar. Water penetrated deeper into Amarillo fsl, which should have caused more water to be stored in that soil. A possible reason for the similar water accumulations is that the two soils had similar water flow characteristics at high water contents, even though their water retention characteristics were markedly different. This was found at the conclusion of the water addition experiment when all columns were wetted to the $-1/3$ bar potential and evaporation was permitted. Water loss from both soils was not greatly different during the first stage of evaporation, especially at the three highest residue rates (data not shown). Under a higher evaporative potential, water accumulation in the two soils may have differed. However, this possibility was not investigated.

Soil water accumulations, as a percentage of the water added during the first 14-day period, were low and increased only slightly as residue rates increased for Pullman cl. For Amarillo fsl, water accumulations were low and erratic for all residue rates, except for the 12,000 kg/ha rate for which water accumulation was the highest. During subsequent periods when water application rates were twice that of the previous period, water accumulations increased as residue rates increased for both soils.

This study shows that little improvement in water storage efficiencies could be expected from applying surface residues, even at relatively high rates, to either soil when precipitation amounts are small. Adding small (0.25 cm) amounts of water on individual days did little more than wet the residues. This water was subsequently almost completely lost by evaporation. Even the 15% storage obtained for Pullman cl during the first 14-day period amounted to only 0.23 cm of water.

When larger amounts of water were added, more water was stored in the soils. However, only for the fourth interval, during which 12.0 cm of water was added, was the amount stored in the check columns (0 kg/ha residues) appreciably above the high of 25% frequently reported for Great Plains soils during fallow (Mathews and Army, 1960). For the entire 56-day period, water stored in the Pullman cl and Amarillo fsl check columns was only 9 and 7% higher, respectively, than the high of 25% often re-

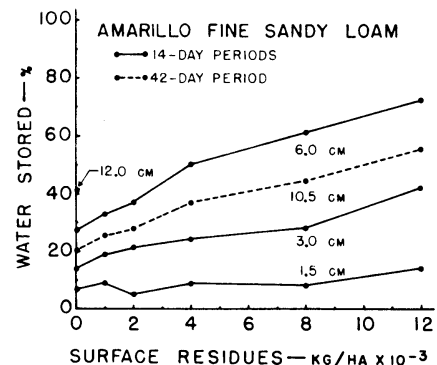


Fig. 2—Water stored in Amarillo fine sandy loam during successive 14-day periods and the 42-day period during which water additions were identical for all treatments. Total water added is shown by numbers at the lines. Least significant differences (0.05 level) were 3.4, 3.5, and 3.3% when 1.5, 3.0, or 6.0 cm of water were added, respectively.

ported for Great Plains soils during fallow. (The 52-day value for Amarillo fsl is not shown in Fig. 2.) While potential evaporation under the study conditions was moderate (0.64 cm/day), all water was added in a time interval shorter than that generally occurring under natural conditions, and no runoff was permitted from the columns. Hence, conditions favored storing a greater fraction of the water in the columns than would be expected under field conditions.

The increased water accumulations resulting from surface residues showed that when adequate residues were present, they could be managed to increase soil water storage during fallow. About 4,000 kg/ha of wheat residues gave complete surface coverage, which resulted in the slope changes in Fig. 1 and 2 for the water storage curves at the higher water applications. On Pullman cl under field conditions, storage efficiencies ranging from 40 to 50% were obtained when irrigated wheat residues, ranging from 5,000 to 11,000 kg/ha at the start of fallow, were maintained on the surface and weeds were controlled with herbicides during fallow (Unger et al., 1971; Unger and Parker, 1975; Unger and Phillips, 1973). While water storage was determined primarily during fallow, indications were that growing season water storage was greater and that row crops utilized more of the growing season precipitation for growth and grain production on residue-covered, no-till seeded areas than on bare soil (Unger and Parker, 1975).

While the water storage capacity of some soils is inadequate to store 50% of the precipitation during typical fallow periods, about 50% storage is necessary to fill Pullman cl and similar profiles to a 1.8-m depth during an 11-month fallow period under average precipitation conditions. Water storage efficiencies under field conditions exceeding 50% were obtained during the first part of fallow after wheat in the Great Plains (Black and Power, 1965; Greb et al., 1970; Smika and Wicks, 1968; Unger et al., 1971; Unger and Phillips, 1973). Obtaining such efficiencies for longer periods remains a challenge under field conditions. By utilizing adequate residues with excellent surface covering characteristics, above 50% storage efficiencies should be possible. If so, then for much of the dryland farming region of the Great Plains, adequate water from precipitation could be stored in soil to fill the profile and, thus, substantially increase production under dryland conditions.

Residue production by dryland crops on the southern Great Plains generally is low and often inadequate for significantly increasing water storage in soil during fallow over that obtained for bare soil (Wiese, et al., 1967). Bond and Willis (1969) suggested that concentrating residues on a portion of the land might prove successful. This experiment supported this possibility. Concentrating residues should increase water storage and crop yields on the receiving area and not materially alter water storage and yields on the contributing area when initial residue levels are too low to increase water storage appreciably over that obtained for bare soil.

When considering removal of residues from cropped areas, the erosion hazards must be considered. Possibly, only a portion of the residues should be removed, leaving the remainder in place for protection against wind or water erosion.

In irrigated areas, another possibility, as proposed by Unger and Phillips (1973), would be to grow irrigated and dryland crops alternately on the same areas. Irrigated crops often produce an abundance of residues. For example, irrigated wheat residues averaged between 6,000 and 7,000 kg/ha during a 5-year study and amounts near 11,000 kg/ha were measured (Unger et al., 1973). Such amounts of residue can cause difficulties in preparing the soil for the next crop in continuous or annual cropping systems. When similar amounts of wheat residue were used as an in-place surface mulch, soil water storage and grain sorghum yields were increased in an irrigated wheat-fallow-dryland grain sorghum system (Unger and Parker, 1975). This system and an alternate irrigated-dryland cropping system for winter wheat are being further evaluated.

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